SEISMIC EVALUATION OF CRANE SUPPORTING INDUSTRIAL STEEL BUILDINGS

A thesis submitted in the partial fulfillment of the requirements for the Degree of

BACHELOR OF TECHNOLOGY
IN
CIVIL ENGINEERING

BY
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UNDER THE GUIDANCE OF
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DEPARTMENT OF CIVIL ENGINEERING

NATIONAL INSTITUTE OF TECHNOLOGY, ROURKELA

2014

DEPARTMENT OF CIVIL ENGINEERING

CERTIFICATE

*This is to certify that the Project Report entitled, "**SEISMIC EVALUATION OF CRANE SUPPORTING INDUSTRIAL STEEL BUILDINGS**" submitted by **Kaushal Kumar** (**Roll-110CE0042**) in partial fulfillment for the requirements for the award of the Degree of Bachelor of Technology in Civil Engineering at National Institute of Technology, Rourkela is an authentic work carried out by them under my supervision and guidance. To the best of my knowledge, the matters embodied in the thesis have not been submitted to any other university/Institute for the award of any Degree or Diploma.*

Department Of Civil Engineering
Place: NIT Rourkela

Date: 10th May 2014

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ACKNOWLEDGEMENT

At this moment I feel grateful and loyal to my supervisor, Prof. Asha Patel for her enthusiastic suggestions and kind help towards me in achieving success of my project. Her constant encouragement and invaluable share of her valuable time with me made such a difficult task so easy. I take this opportunity to express our heartfelt gratitude to all those who helped me in various ways during our project at NIT Rourkela. I also express our sincere gratitude to Prof. N. Roy, Head of the Department, Civil Engineering, and Prof. Ramakar Jha for providing valuable departmental facilities. I would like to use this opportunity to express my gratitude to all the faculty members of the Civil Engineering Department who played a vital role in bringing me to this level.

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Date: 10th May 2014

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ABSTRACT

The aim of the present study is to investigate the effect of earthquake on regular mill type crane supporting industrial steel frame. To evaluate the seismic performance of the frame , response at supported end of gantry girder(to be referred as point of observation) is studied by performing Equivalent Static ,Response spectrum and Time History Analysis methods . Since the response of the frame is affected by the position of the loads on crane and location of crane on gantry girder ,the analysis is performed considering different positions of crane girder with respect to the point of observation. For the present study the extreme position of crane hook with minimum approach is considered.
The results of analysis indicate that when the crane is located at the point under observation the deflections are less and increase when crane moves away. The variation occurs when crane is positioned in spans adjacent to the point of observation and beyond that the variation are minimul. Therefore crane positions next to adjacent spans are not considered in the present study. Comparision of results obtained by the three methods of analysis are compared and discussed.

STAAD Pro is used for the design and analysis.

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CHAPTER-1

INTRODUCTION

Seismic Analysis is a branch of structural analysis and is the computation of the response of a structure to earthquakes. The loading is applied to a structure by an earthquake which is usually a ground movement with both horizontal and vertical components. The horizontal movement is the most unmistakable characteristic of earthquake action as its strength is higher and additionally on the grounds that structures are by and large planned to oppose gravity forces as opposed to horizontal forces. The vertical component of the earthquake is usually about half of the horizontal component, aside from in the region of the epicenter where it could be of the same intensity.

Steel structures are typically great at opposing earthquakes because of their ductile nature. Generally when steel structures are subjected to earthquakes, they carry on well. But as these structures are subjected to lifting heavy loads, earthquake forces become hazardous during lifting and/or moving of heavy loads.

A crane girder is a preformed metal shaft over which the crab or hoist head of a voyaging overhead crane runs. Such girders are generally "I" profile beams that may be fortified at different focuses relying upon the loads and crane setup included. They may offer a few crane girder formats, for example, single girder, double girder, or bridge girder outlines. The arrangement depends to a great extent on the headroom in the building and the loads the crane is intended to lift.

Gantry girders or crane-runway lifting girders are provided in almost all industrial buildings for lifting and transportation of heavy loads. The wheels of the crane girder move onward the rails mounted on the gantry girders. The rails provide a fairly constant span for movement of the crane girder. Its variation ought not to be more than 10mm on either side. A gantry girder is subjected to a variety of often severe stresses during lifting operations. The function of the crane girders is to support the rails on which the traveling cranes move. These are subjected to vertical loads from crane, horizontal lateral loads due to surge of the crane, that is, the effect of acceleration and braking of the loaded crab and swinging of the suspended load in the transverse direction, and longitudinal force due to acceleration and braking of the crane as a whole.

The aim of the present work is to study the dynamic behavior of single bay single wheeled overhead crane (without cabin) supporting steel frame. The crane loads and its movements along the gantry girder dominate the design of many structural elements in crane supporting structures. The crane wheels move on rail mounted on gantry girder which in turns is supported on columns.

The crane load acts like a moving static wheel load on the supporting gantry girder. Hence the position of the crane guide influences the behavior of gantry girder under earthquake load.

In the present study, effect of the movement of crane girder is studied by analyzing the gantry girder under earthquake loads. The seismic behavior of gantry girder is performed and compared by using different methods of seismic analysis like-

- ✓ Equivalent Static Load method,
- ✓ Response Spectrum Method and
- ✓ Time History Method.

CHAPTER-2

PROBLEM STATEMENT

The frame to be analyzed will be a 20m wide X100m long building of height 12m. There is a crane of capacity 100 tons supported on gantry girder system supported by concentrically braced column sections at spacing of 5m center to center.

The crane beam is situated at a height of 8m and is supported on gantry girder which connected to the braced I-section columns with the help of brackets.

The roof of the building is a Pratt Truss system with a height of 2m. All the design and analysis of the building will be done using STAAD.Pro V8i.

The seismic parameters of building site are as follows

- Seismic zone: 4
- Zone factor (Z): 0.24
- Building frame system: Steel Frame with eccentric braces.
- Response reduction factor: 5
- Importance factor: 1.5
- Damping ratio: 3%

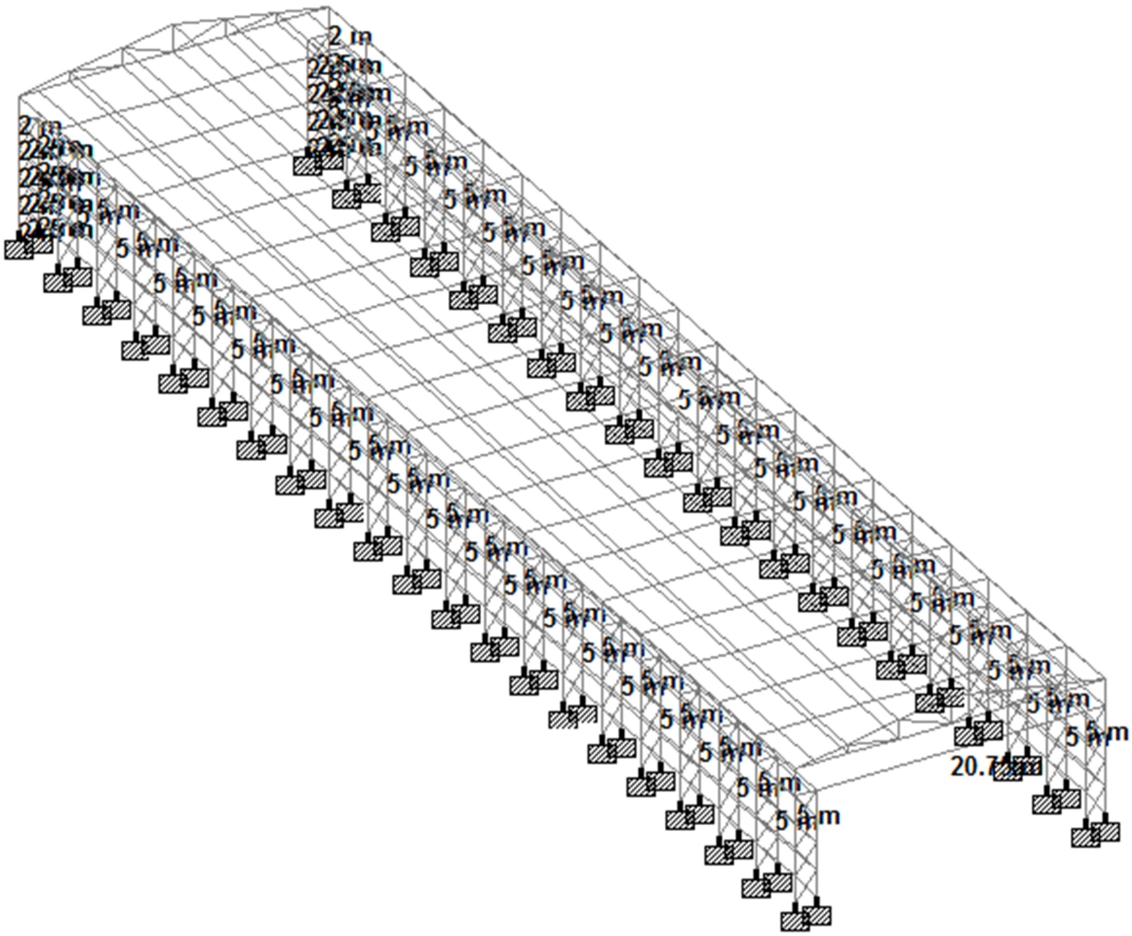

FIG 2.1: 3-dimensional view of the steel building frame

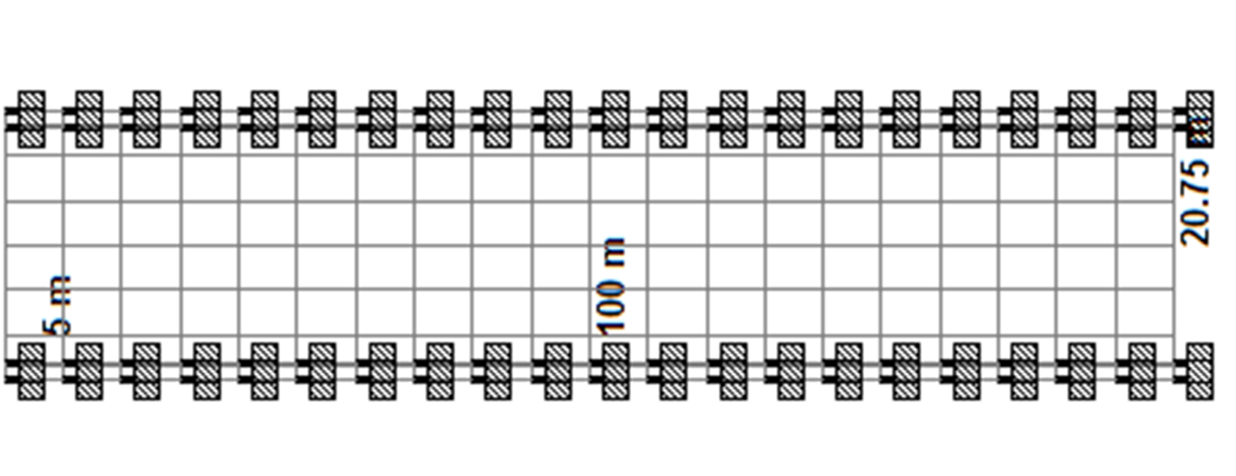

FIG 2.2: Plan of the building frame

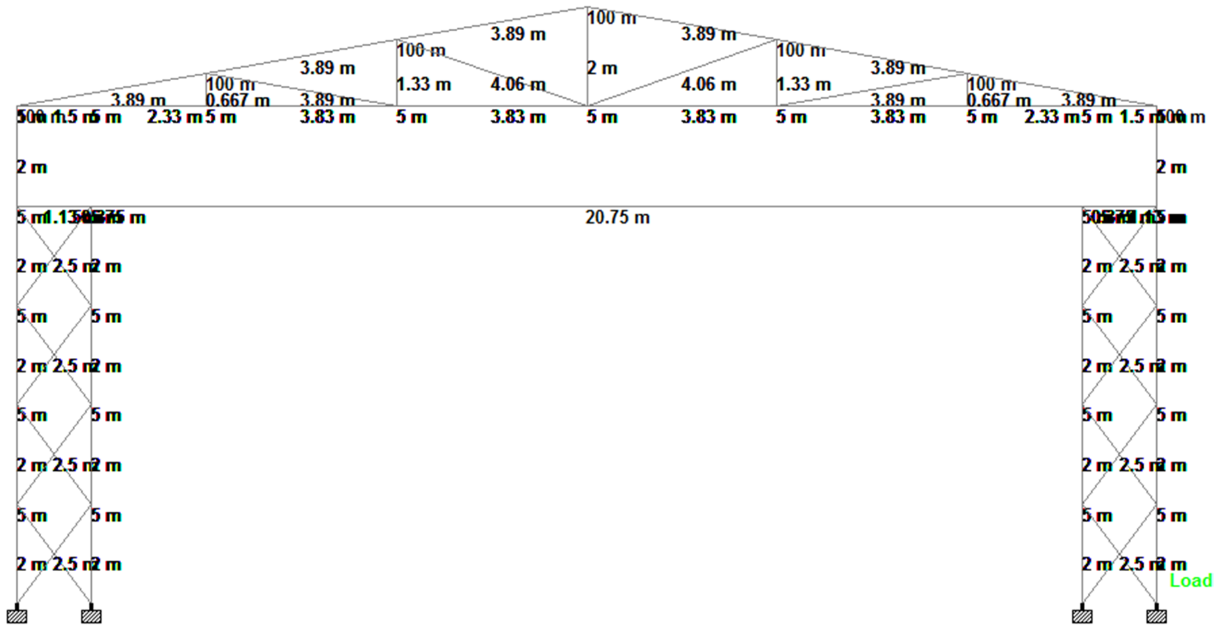

FIG 2.3: Elevation of the building frame (Front view)

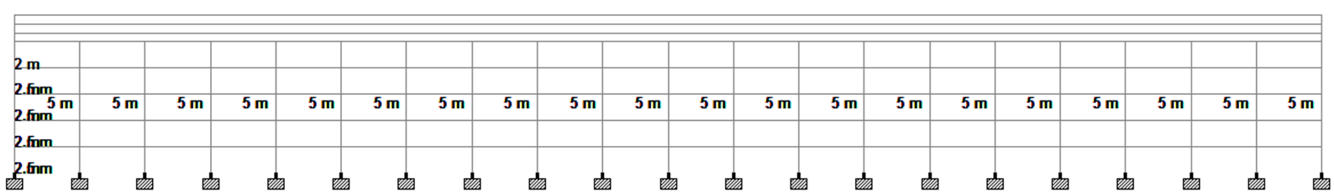

FIG 2.4: Elevation of the building frame (Side view)

CHAPTER-3

METHODOLOGY

Step1

Design of each element under gravity loading of the industrial frame which consists of

- ✓ Crane Girder
- ✓ Gantry girder
- ✓ Supporting columns
- ✓ Roof Truss

Initially it is done manually.Then optimised by using STAAD.Pro.

Crane Girder

It is a single wheeled at both ends without cabin crane girder .

Loading-

- ✓ Crane Capacity= 100tonnes
- ✓ Self weight

After manual analysis of these forces, the section obtained for the crane girder is-

Crane Girder- ISMB 600

Gantry Girder

It is hinge supported on the bracket at columns. The wheels of the crane girder move on the rails mounted on the gantry girders

Loading-

- ✓ Vertical Loading (Maximum Static Wheel Load from crane girder including self weight of rail section)=300.25kN (25% extra is taken to allow for impact load etc.)
- ✓ Horizontal Loading (Lateral Surge Load)=10kN (10% of crane load)
- ✓ Horizontal Loading (Longitudinal Braking Load)= 15.2625kN (5% of static wheel load)

Moment-

- ✓ Vertical maximum bending moment(Mx)= 381.5625kN
- ✓ Horizontal bending moment (My)= 9.50625kN
- ✓ Bending moment due to drag(assuming the rail height as 0.15m and depth of girder as 0.6m)= 2.232kN
- ✓ Total design bending moment(Mz)= 392.7kN

Shear Force-

- ✓ Vertical shear force(Vz)= 403.95kN
- ✓ Lateral shear force due to surge load(Rz)=405.33kN

After designed for these forces, the sections obtained for the gantry girders are- Built up section of ISMB 550 with ISMC 300 on top with a weld of 4mm (500N/mm per weld) having a web stiffener of 90mm c/c depth.

Column Section-

Columns are designed for the axial loads.

Loading-

Vertical Loading(on each column) =276.65kN

After manual analysis of these forces, the sections obtained are-

Column Section- Double I-sections of ISMB 600 specifications with eccentric bracing using 20mmX5mm bracing sections.

Batten- 200mmX200mm plates with 10 30mm HSFG bolts.

Roof Truss-

Loading-

- ✓ Dead Load(DL) =0.21kN/m^2
- ✓ Live Load (LL) =0.4kN/m^2
- ✓ Load normal to Z axis (Wz) = 1.526kN/m
- ✓ Load normal to Y axis (Wy) = 0.305kN/m
- ✓ Horizontal Moment(My) =1.89375kNm

- ✓ Vertical Moment(Mz) = 4.4725kNm
- ✓ Vertical Shear Force(Vz) = 4.4725kN

After manual analysis of these forces, the sections obtained are-

Purlin- ISMC100

Tie member and Web Member- ISA 25mmX25mmX5mm

<u>Step2</u>

Modelling the frame in STAAD .

During modelling some elements are offset for example Crane Girder is mounted on Rail which is installed on top of the Gantry Girder . The traction force and lateral force act at rail level . During analysis only longitudinal force is considered because as per the code IS 800 either lateral or longitudinal force acts.

At some nodes certain degree of freedoms are released.For example at base of gantry girder moment about longitudinal axis is released to allow it to rotate .

<u>Step3</u>

Load calculation:

In the present study crane load is not considered seperately but taken as live load. Hense the load combinations considered for analysis are :

- ✓ 1.5(DL+LL)
- ✓ 1.2(DL+LL±EL) { where DL- Dead Load
- ✓ 1.5(DL±EL) EL- Earthquake Load
- ✓ 0.9DL±1.5EL LL- Live Load}

<u>**Step4**</u>

Analysis :

The frame is analysed for positions of crane girder as shown in the **FIG 3.1** below. Equivalent Static Load Method ,Response spectrum Method and Time History methods of analysis are used. Seismic responses like deflections along x and z directions are determined at point O,base shears, participation factors are determined for different position of loading and results are compared.

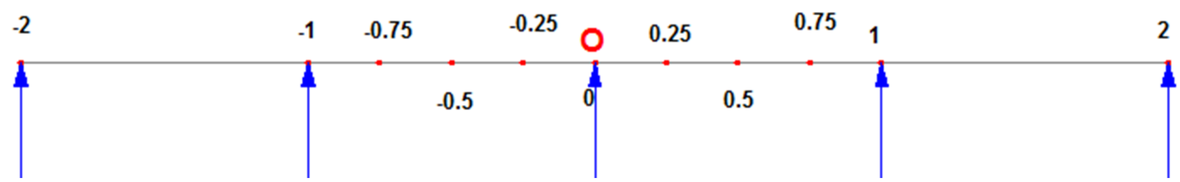

FIG 3.1: Crane positions on the gantry girder (point of observation is O)

CHAPTER-4

ANALYSIS

Three methods of analysis are considered in the analysis of the structure-

- Equivalent Static Load analysis
- Response Spectrum analysis
- Time History analysis

Analysis are based on IS1893 (Part1): 2002

- **Equivalent Static Load Analysis-**

✓ Equivalent Static Load Method (ESLM) is based on the assumption that whole of the seismic mass of the structure vibrates with a single time period calculuated. This method does not require dynamic analysis of the structure hence called Eqivalent Static Load method.

✓ It is a highly crude method used for initial estimation of the response of the structure.

✓ It is not advisable for large and/or complex structures.

- **Response Spectrum Analysis-**

✓ This method is based on the dynamic analysis of structure. First a free vibration analysis is performed to determined the time periods and mode shapes of the structure in different modes.

✓ The response in various modes including the base shear can be combined using CQC,SRSS etc combinations. In the present study SRSS combinations has been used.

- **Time History Analysis-**

✓ It is an analysis of the dynamic response of the structure at each increment of time, when its base is subjected to a particular ground motion time history. Then again, recorded ground motions database from past natural events can be a reliable source for time histories but they are not recorded in any given site to incorporate all seismological attributes suitable for that site.

- ✓ Analysis of a structure over increment time steps as a function of –
- Acceleration,
- Force,
- Moment, or
- Displacement.
- ✓ It provides the response of a structure over time during and after the application of a load.
- ✓ The Time History Analysis of a structure is simply the response (force or motion) of the structure evaluated as a function of time including inertial effects.
- ✓ Two earthquake response data are considered in analyzing the structure- El Centro, California(1940) and Taiwan (1935).

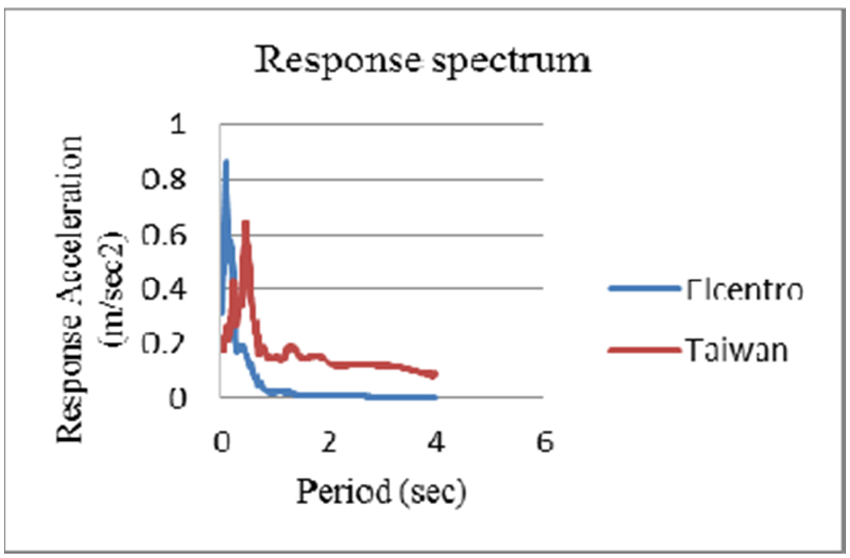

FIG 4.1: Earthquake data used for Taiwan and El Centro earthquakes.

CHAPTER-5

RESULTS AND DISCUSSION

The results obtained from the analysis are -

<u>Equivalent Staic Load Analysis</u>

Table 5.1: Base Shear and member force (for EQX)

Crane Position from point O	Base Shear (kN)	Force (in kN)
0	611.28	212.86
1	528.91	193.18

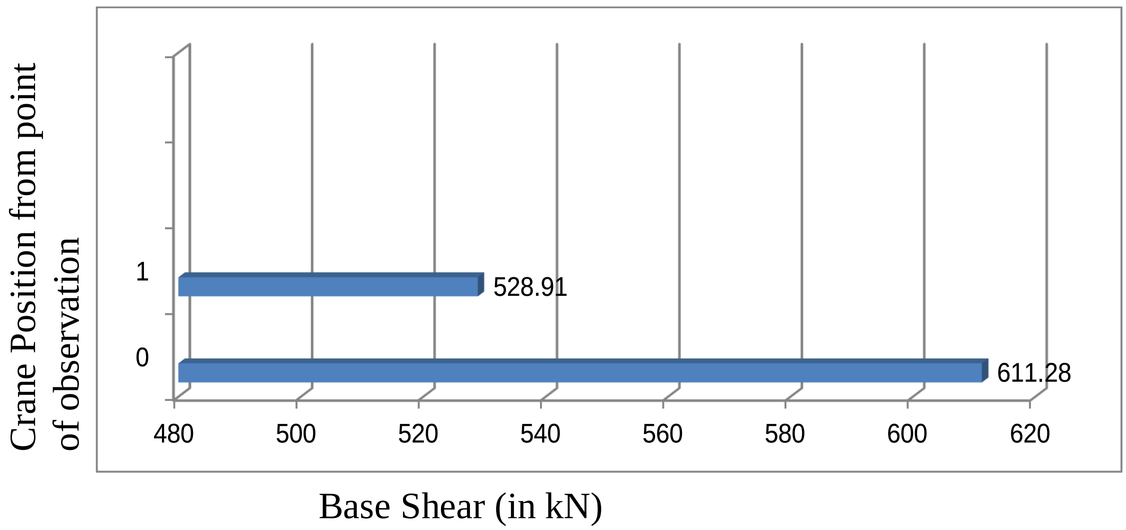

FIG 5.1: Bar Graph of Base Shear vs Crane Position from point of observation.

Table 5.2: Displacement of point of observation for different crane position (Earthquake load along X direction)

Crane Position from point O	Displacement in X (in mm)	Displacement in Z (in mm)
-1	-0.468	-0.32
-0.75	-0.313	-0.18
-0.5	-0.142	-0.095
-0.25	-0.065	-0.033
0	0	0
0.25	0.065	0.033
0.5	0.142	0.095
0.75	0.313	0.18
1	0.468	0.32

***(negative represents towards left and positive represents towards right of point of observation)**

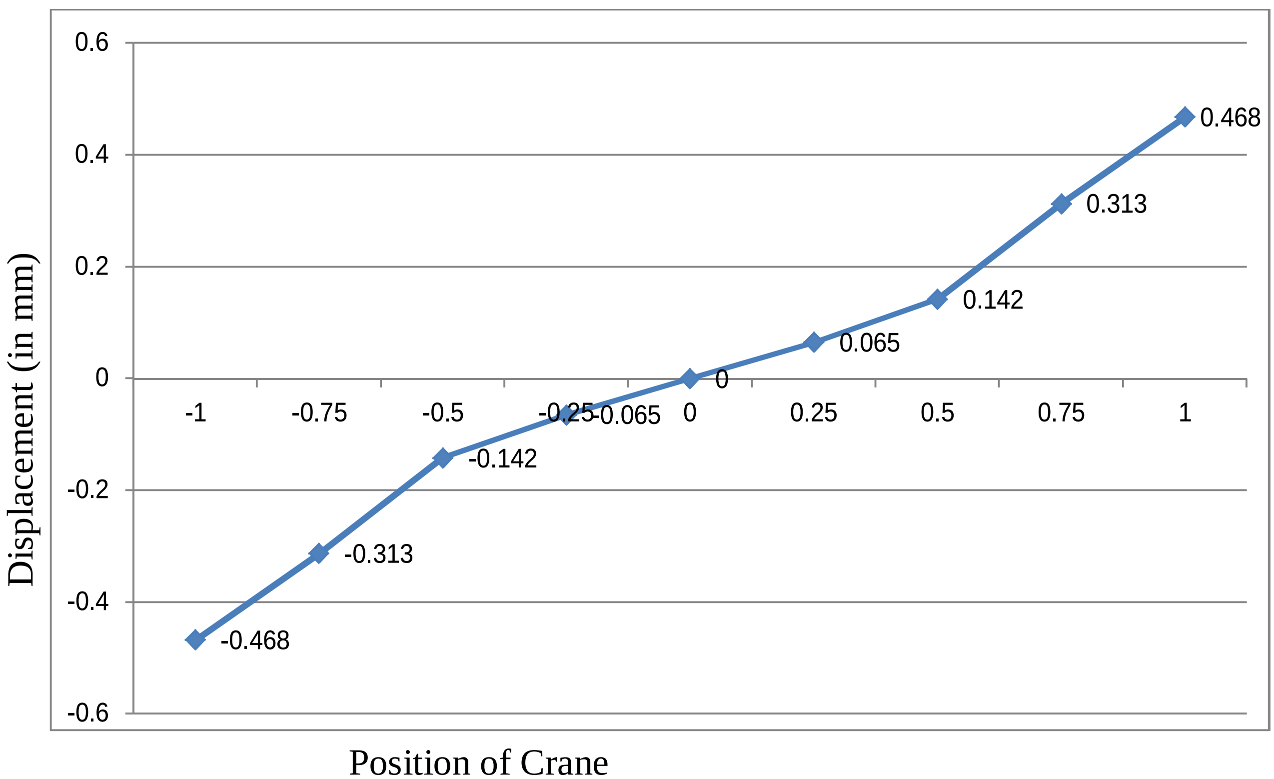

FIG 5.2: Displacement in X-Direction for Equivalent Staitic Load analysis.

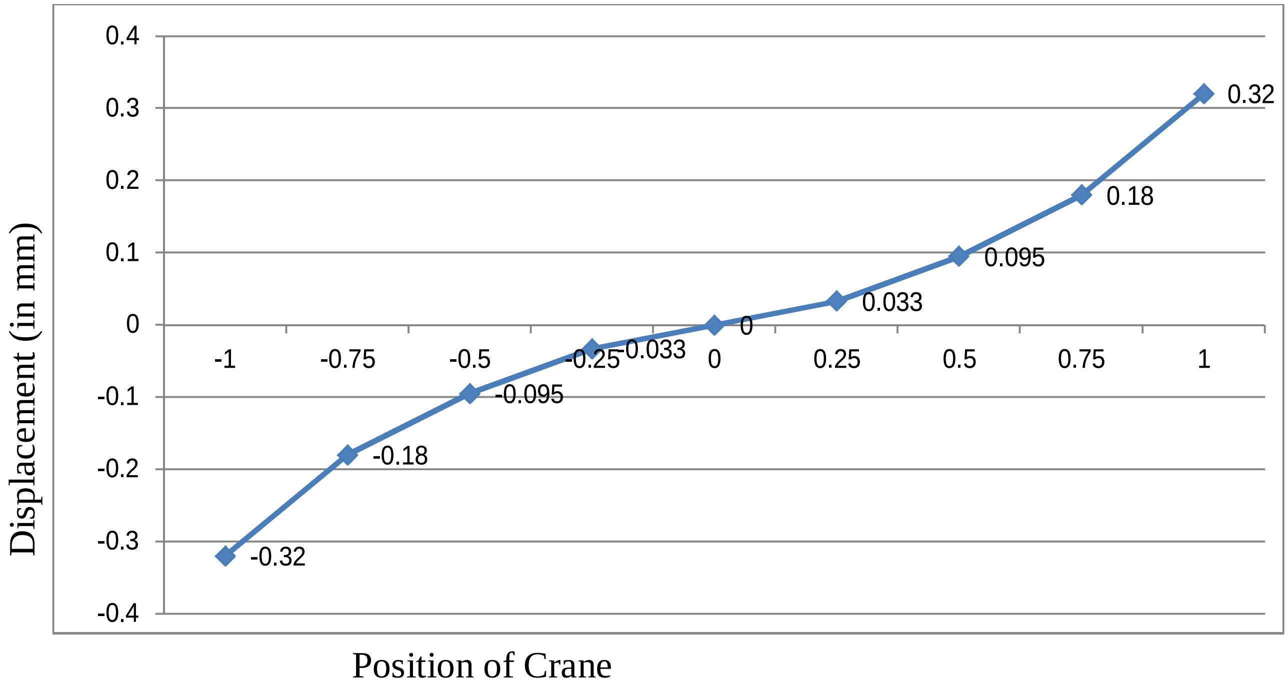

FIG 5.3: Displacement in Z-Direction for Equivalent Staitic Load analysis.

Response Spectrum Analysis

Analysis is done for the earthquake along X direction.

Table 5.3: Base Shear and Modal Participation factor for crane location at point O

Mode	Base Shear(kN)	Modal Participation Factor (%)
1	389.53	82.64
2	32.44	10.28
3	16.82	2.08
4	0.87	0.01
5	1.46	0.87
6	10.85	1.02

Table 5.4: Base Shear and Modal Participation factor for crane location at point 1

Mode	Base Shear(kN)	Modal Participation Factor (%)
1	364.38	83.87
2	23.12	9.67
3	12.87	1.74
4	0.64	0.006
5	0.98	0.64
6	7.32	0.89

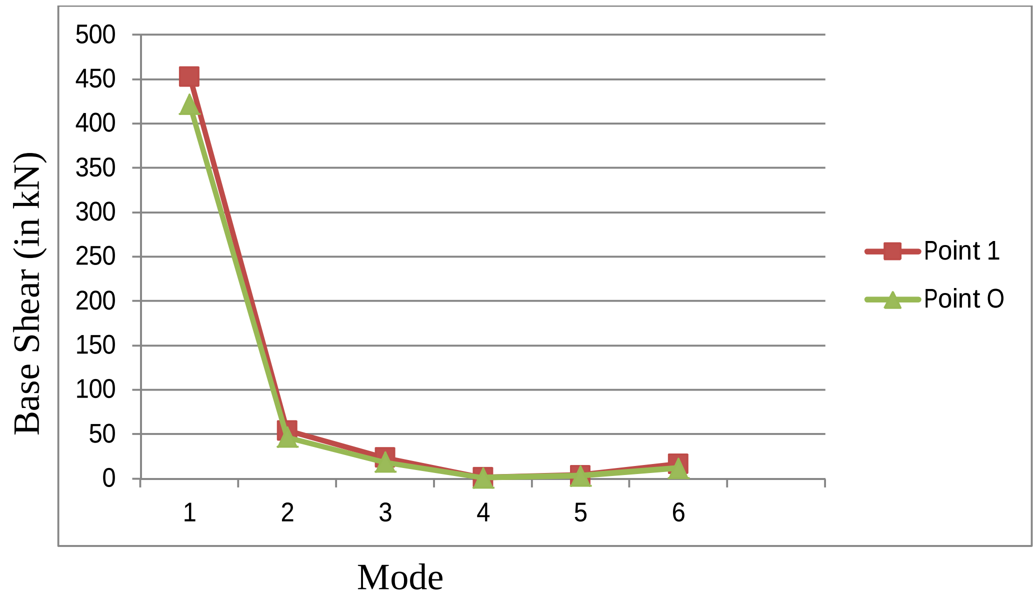

FIG 5.4: Graph of modes vs Base Shear for Response Spectrum Analysis.

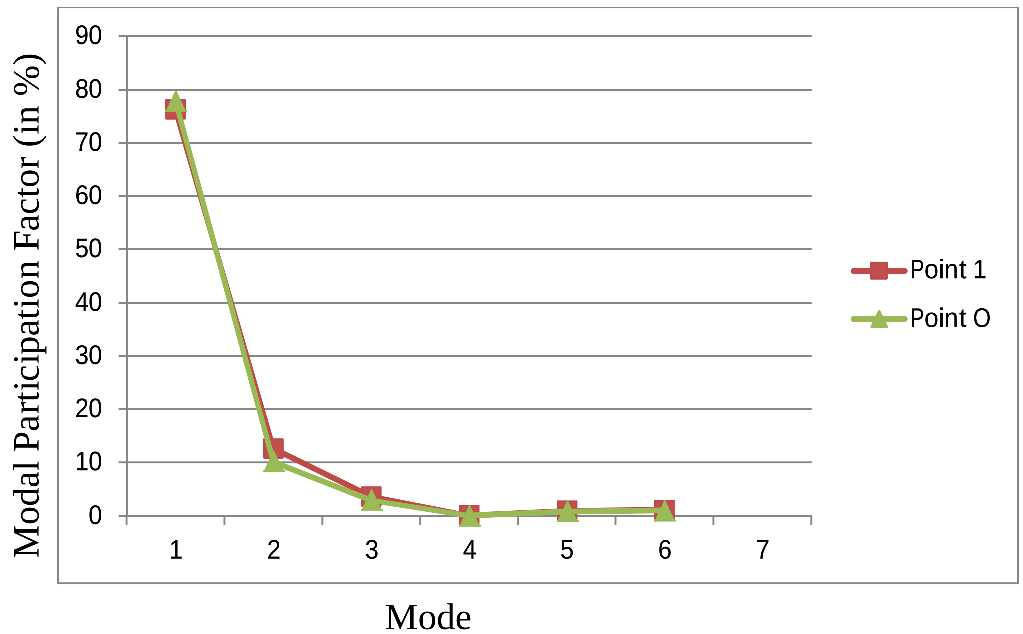

FIG 5.5: Graph of Modes vs Modal Participation Factor for Response Spectrum Analysis.

Table 5.5: Displacement of point of observation for different crane position along X direction

Crane Position from point O	Displacement due to Earthquake along X (in mm)	Displacement due to Earthquake Z (in mm)
-1	-0.393	-0.204
-0.75	-0.254	-0.125
-0.5	-0.135	-0.063
-0.25	-0.06	-0.011
0	0	0
0.25	0.06	0.011
0.5	0.135	0.063
0.75	0.254	0.125
1	0.393	0.204

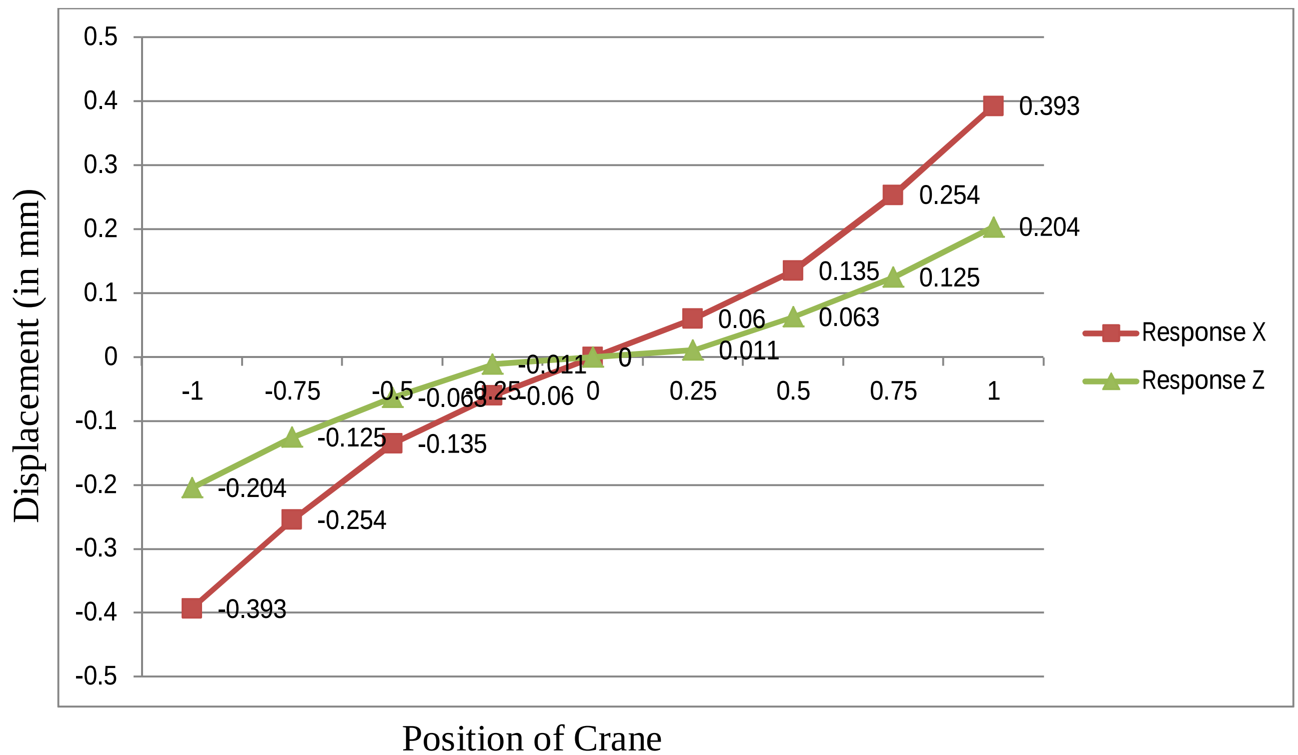

FIG 5.6: Displacement in X-Direction for Response Spectrum analysis.

Table 5.6: Displacement of point of observation for different crane position along Z direction

Crane Position from point O	Displacement due to Earthquake along X (in mm)	Displacement due to Earthquake Z (in mm)
-1	-0.316	-0.313
-0.75	-0.176	-0.172
-0.5	-0.09	-0.086
-0.25	-0.025	-0.022
0	0	0
0.25	0.025	0.022
0.5	0.09	0.086
0.75	0.176	0.172
1	0.316	0.313

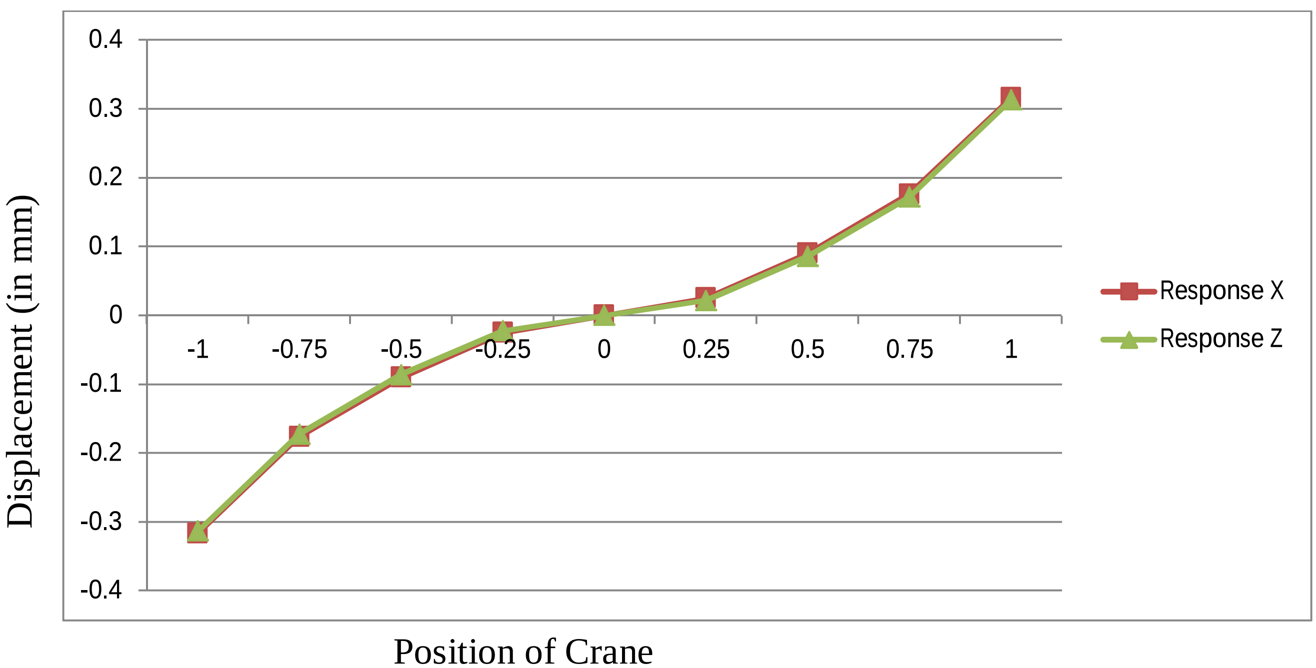

FIG 5.7: Displacement in Z-Direction for Response Spectrum analysis.

Time History Analysis

Table 5.7: Base Shear and Modal Participation Factor for crane loaction at point O

Mode	Base Shear(kN)	Modal Participation Factor (%)
1	453.15	76.24
2	54.62	12.63
3	23.74	3.67
4	1.45	0.12
5	3.83	0.93
6	16.78	1.15

Table 5.8: Base Shear and Modal Participation Factor for crane loaction at point 1

Mode	Base Shear(kN)	Modal Participation Factor (%)
1	421.68	77.89
2	46.76	10.21
3	18.93	2.98
4	1.11	0.07
5	3.14	0.85
6	11.82	1.02

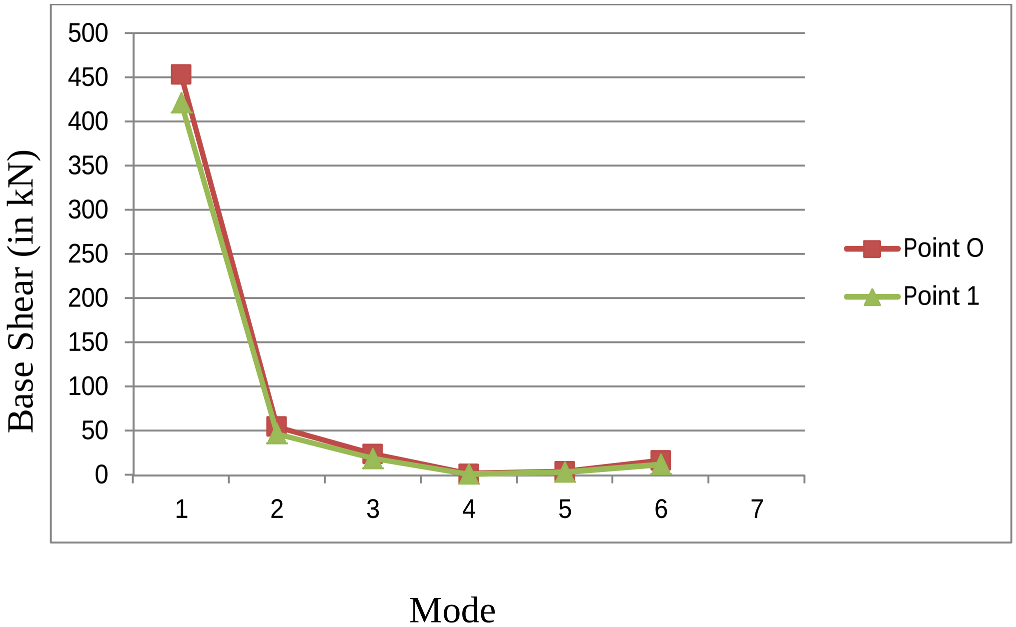

FIG 5.8: Graph of Modes vs Base Shear for Time History Analysis.

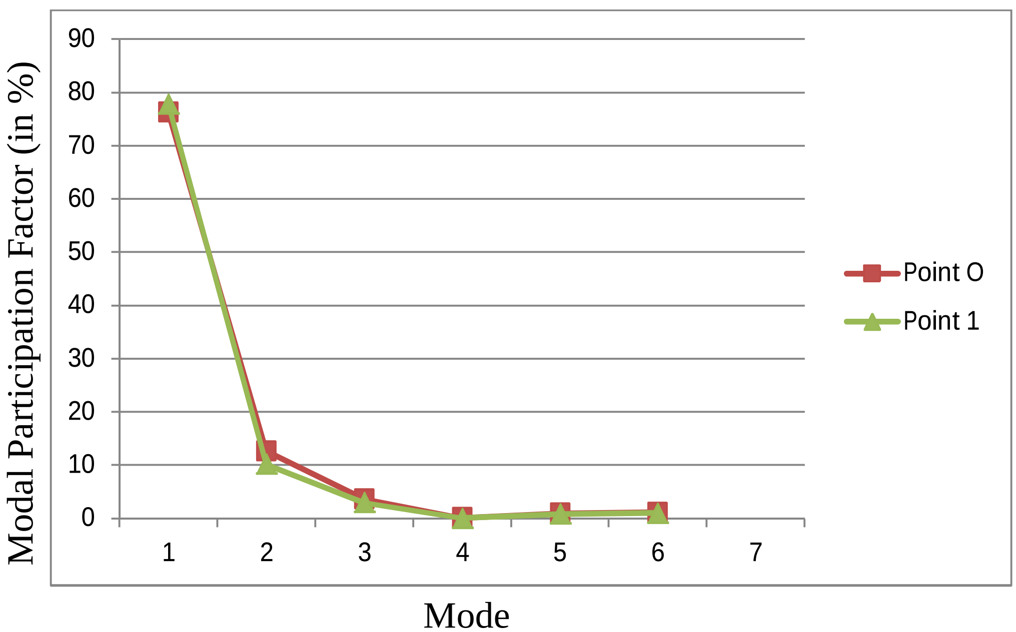

FIG 5.9: Graph of Modes vs Modal Participation Factor for Time History Analysis.

Table 5.9: Displacement of point of observation for different crane position along X direction

Crane Position from point O	Displacement due to El Centro earthquake (in mm)	Displacement due to Taiwan earthquake (in mm)
-1	-0.286	-0.333
-0.75	-0.183	-0.214
-0.5	-0.098	-0.106
-0.25	-0.016	-0.02
0	0	0
0.25	0.016	0.02
0.5	0.098	0.106
0.75	0.183	0.214
1	0.286	0.333

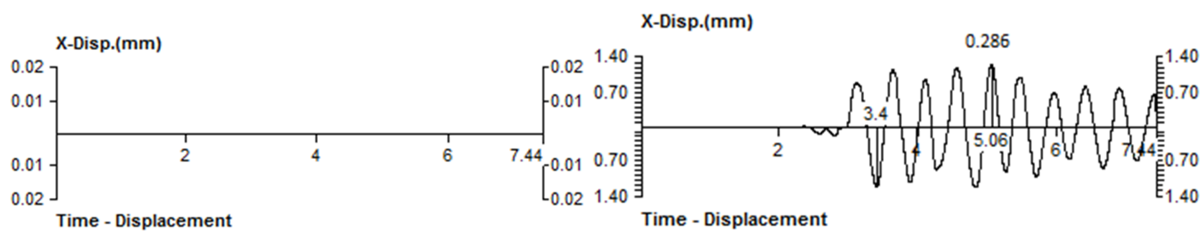

FIG 5.10: Displacement along X-direction for El-Centro Earthquake for point O and point 1 respectively.

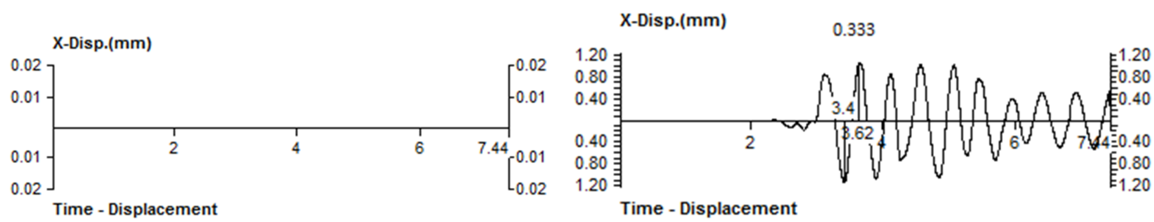

FIG 5.11: Displacement along X-direction for Taiwan Earthquake for point O and point 1 respectively.

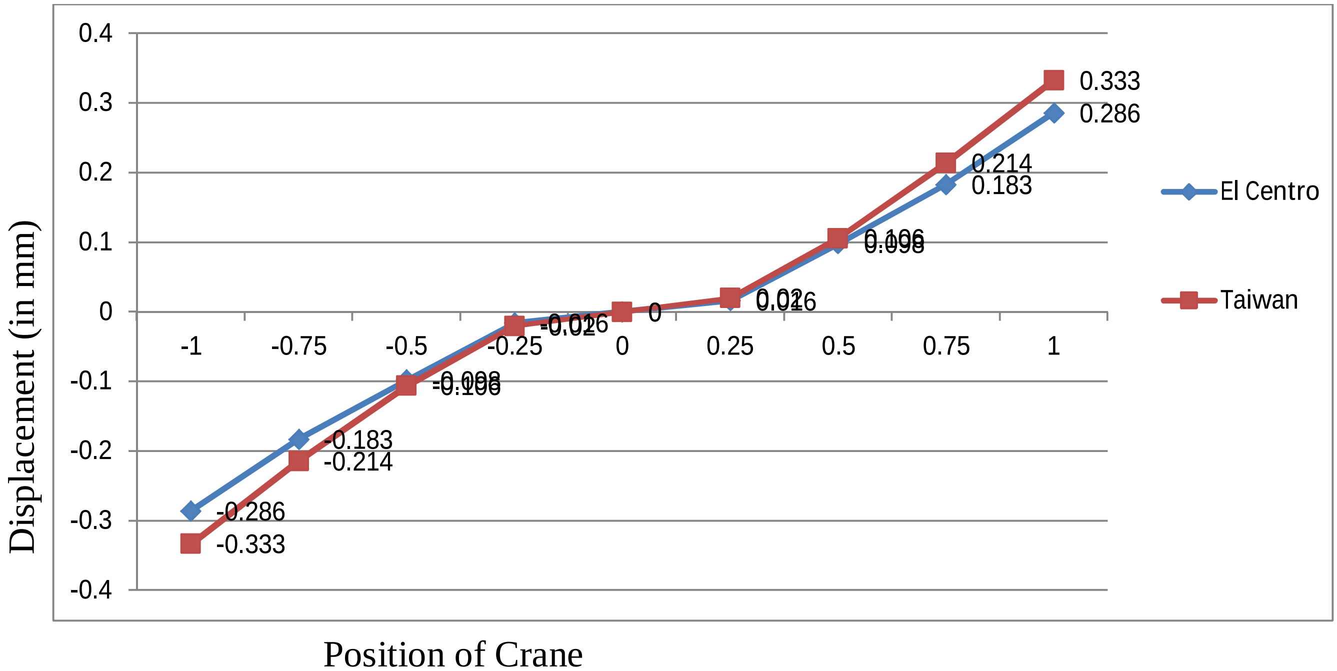

FIG 5.12: Displacement in X-Direction for Time History analysis

Table 5.10: Displacement of point of observation for different crane position along Z direction

Crane Position from point O	Displacement due to El Centro earthquake (in mm)	Displacement due to Taiwan earthquake (in mm)
-1	-0.183	-0.254
-0.75	-0.125	-0.154
-0.5	-0.064	-0.075
-0.25	-0.018	-0.02
0	0	0
0.25	0.018	0.02
0.5	0.064	0.075
0.75	0.125	0.154
1	0.183	0.254

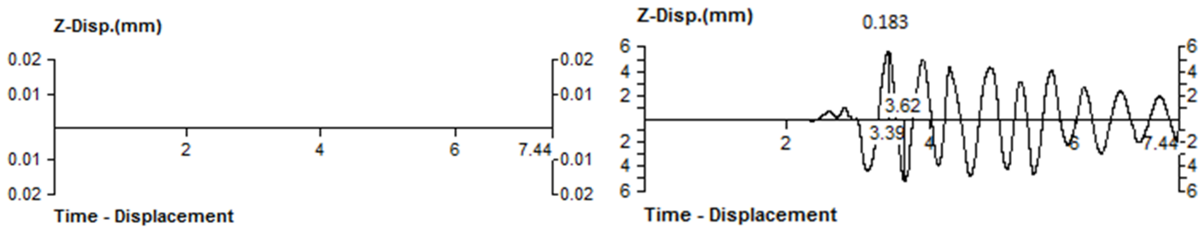

FIG 5.13: Displacement along Z-direction for El-Centro Earthquake for point O and point 1 respectively.

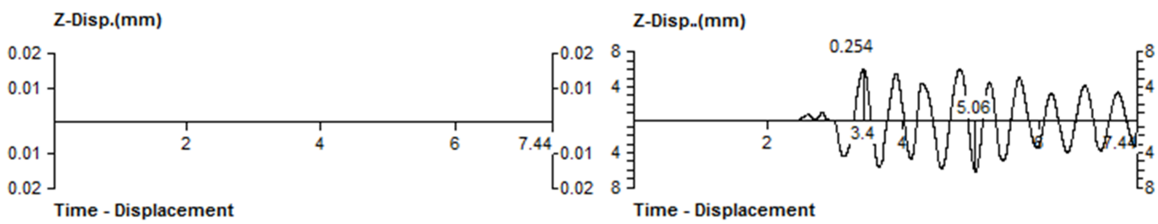

FIG 5.14: Displacement along Z-direction for Taiwan Earthquake for point O and point 1 respectively.

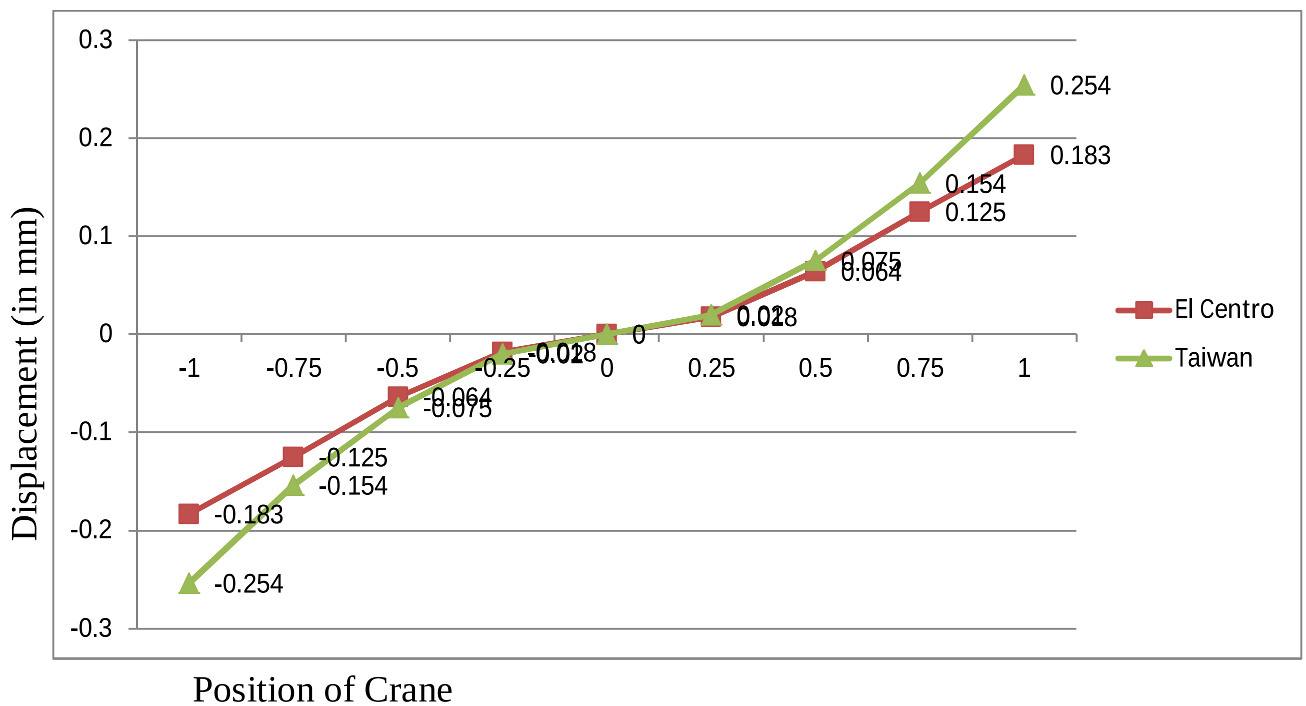

FIG 5.15: Displacement in Z-Direction for Time History analysis.

Table 5.11: Base Shear Comparision

Sl.no.	Method	Max. Base Shear (in kN)
1	Equivalent Staic Load Analysis	611.28
2	Response Spectrum Analysis	389.53
3	Time History analysis	453.15

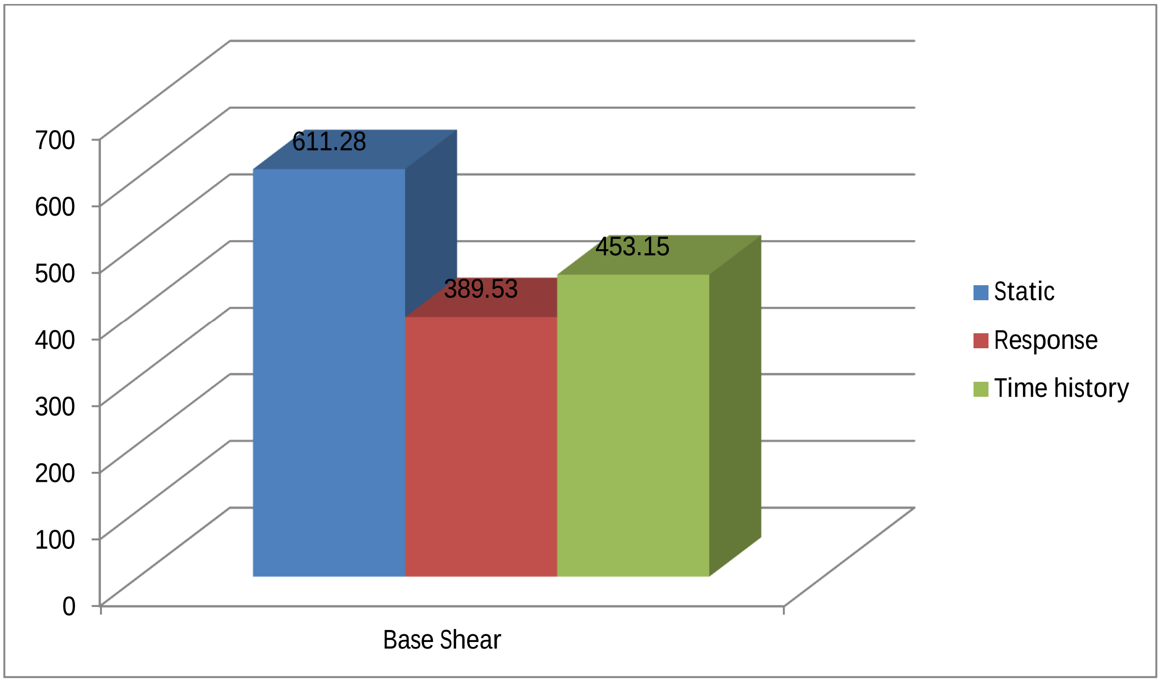

FIG 5.16: Bar Graph of Base Shear vs Analysis methods used.

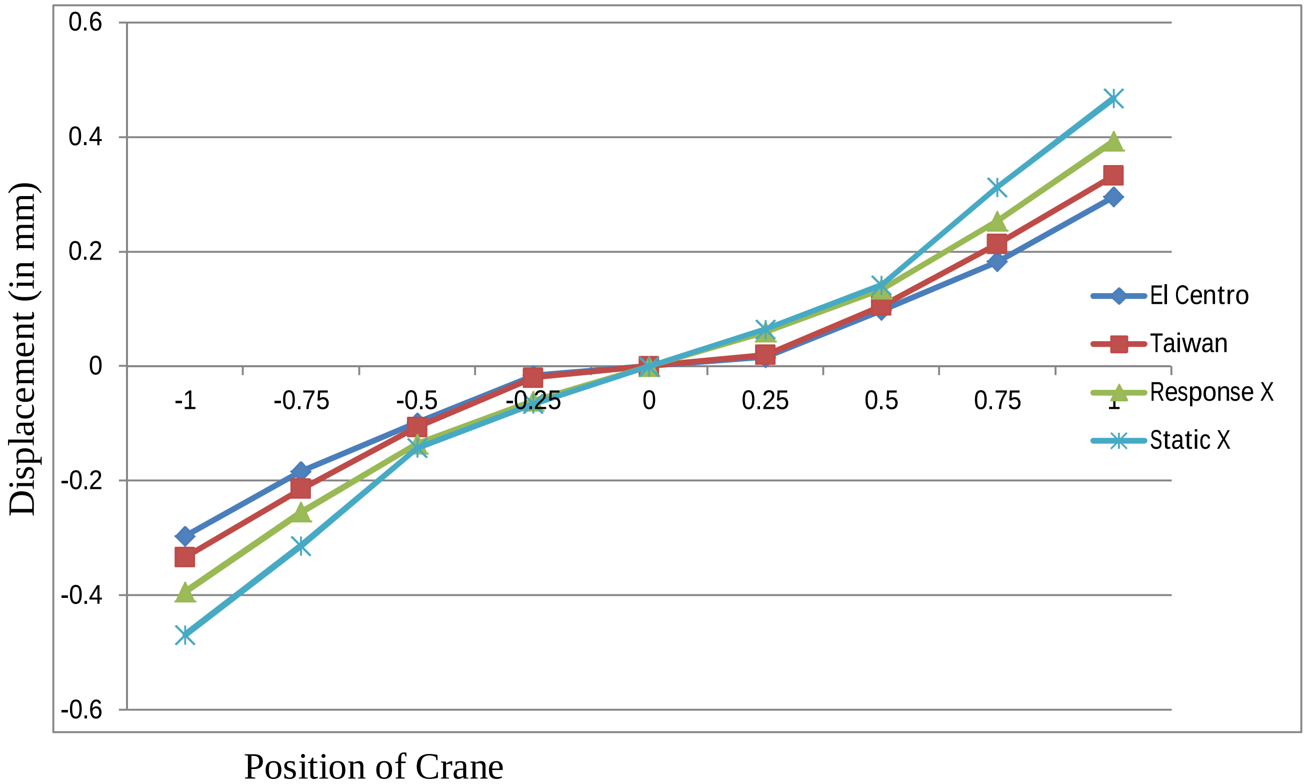

FIG 5.17: Displacement Comparison along X-Direction for EQX

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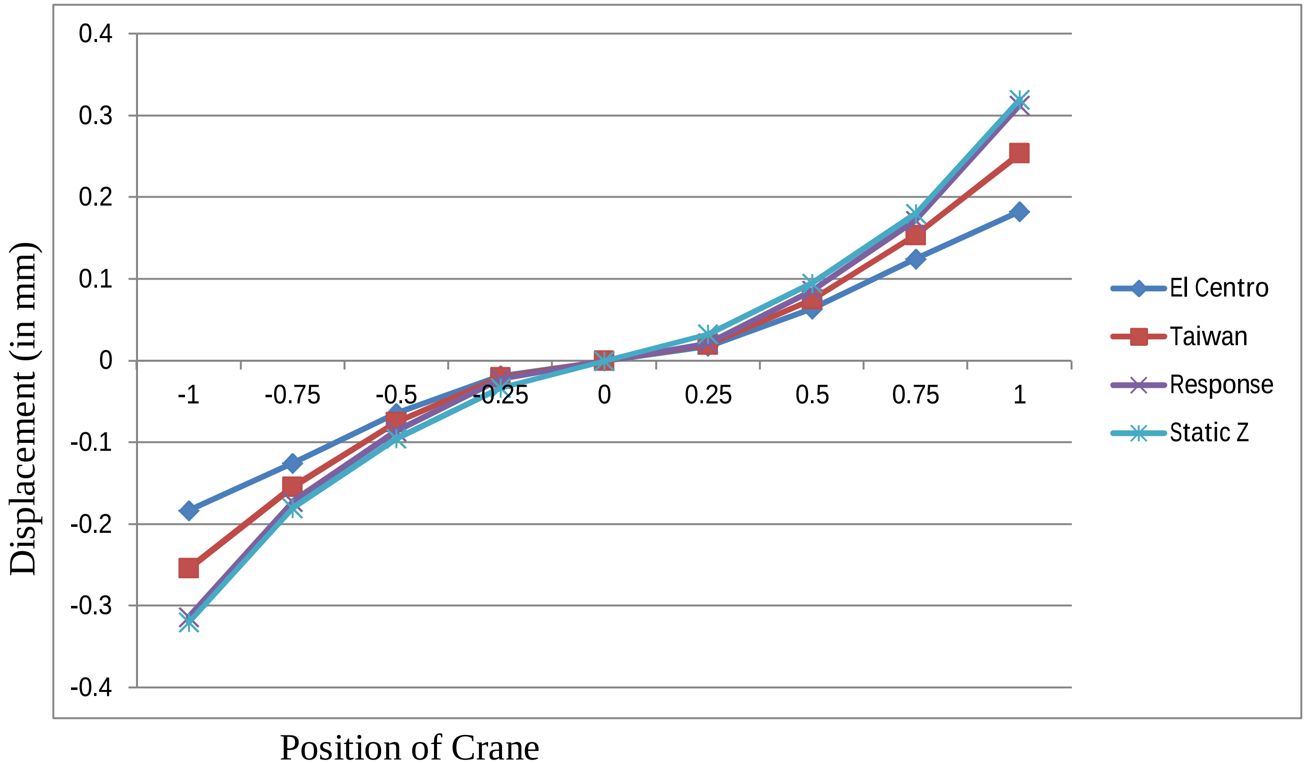


FIG 5.18: Displacement Comparison along Z-Direction for EQX

The trend of displacement variation obtained by the three methods are similar when earthquake forces are acting along X or Z directions.

Displacement obtained along X and along Z are maximum in Equivalent Static load method and minimum in Time History analysis.

FIG 5.19: Mode Shapes for Response Spectrum

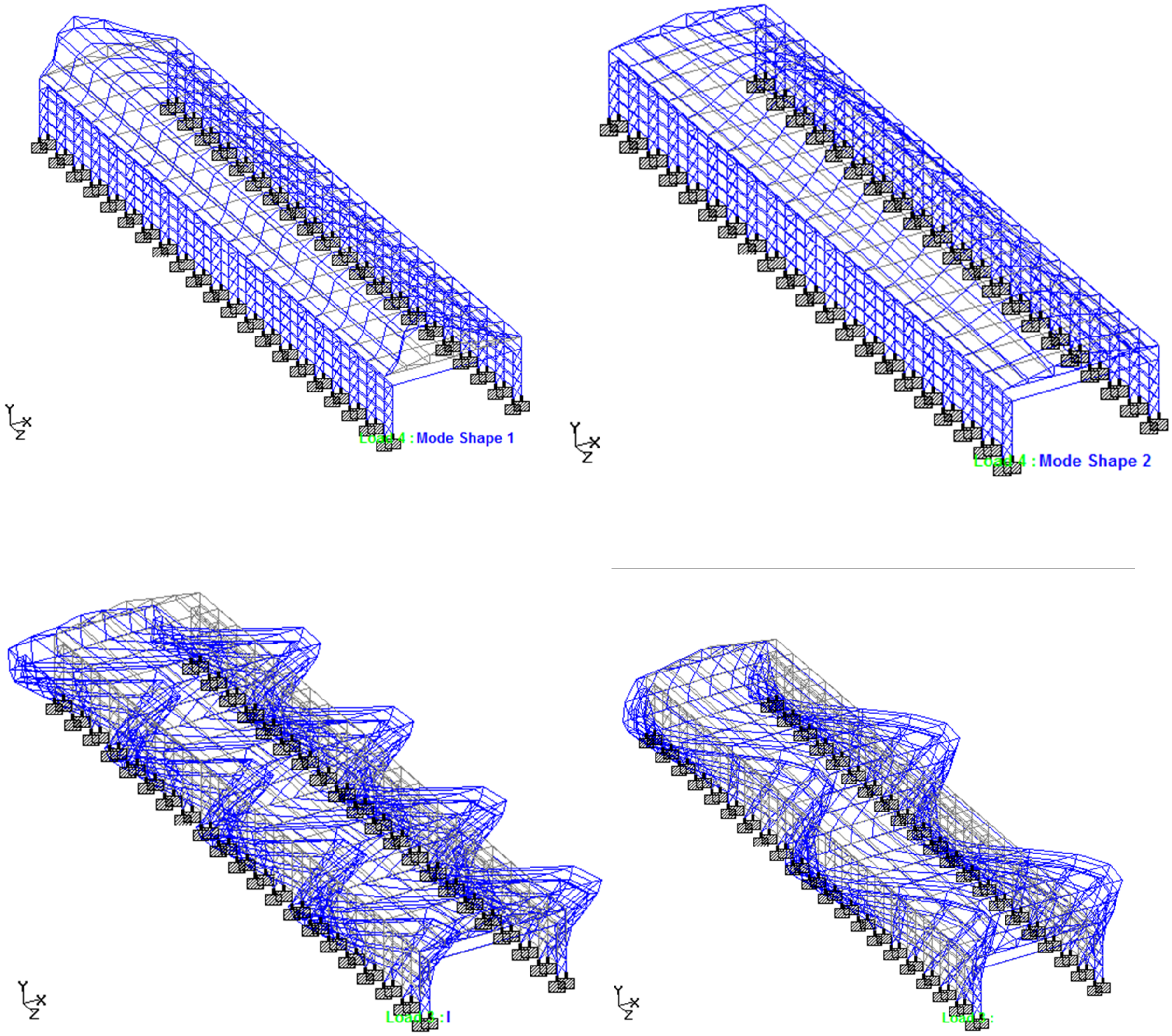
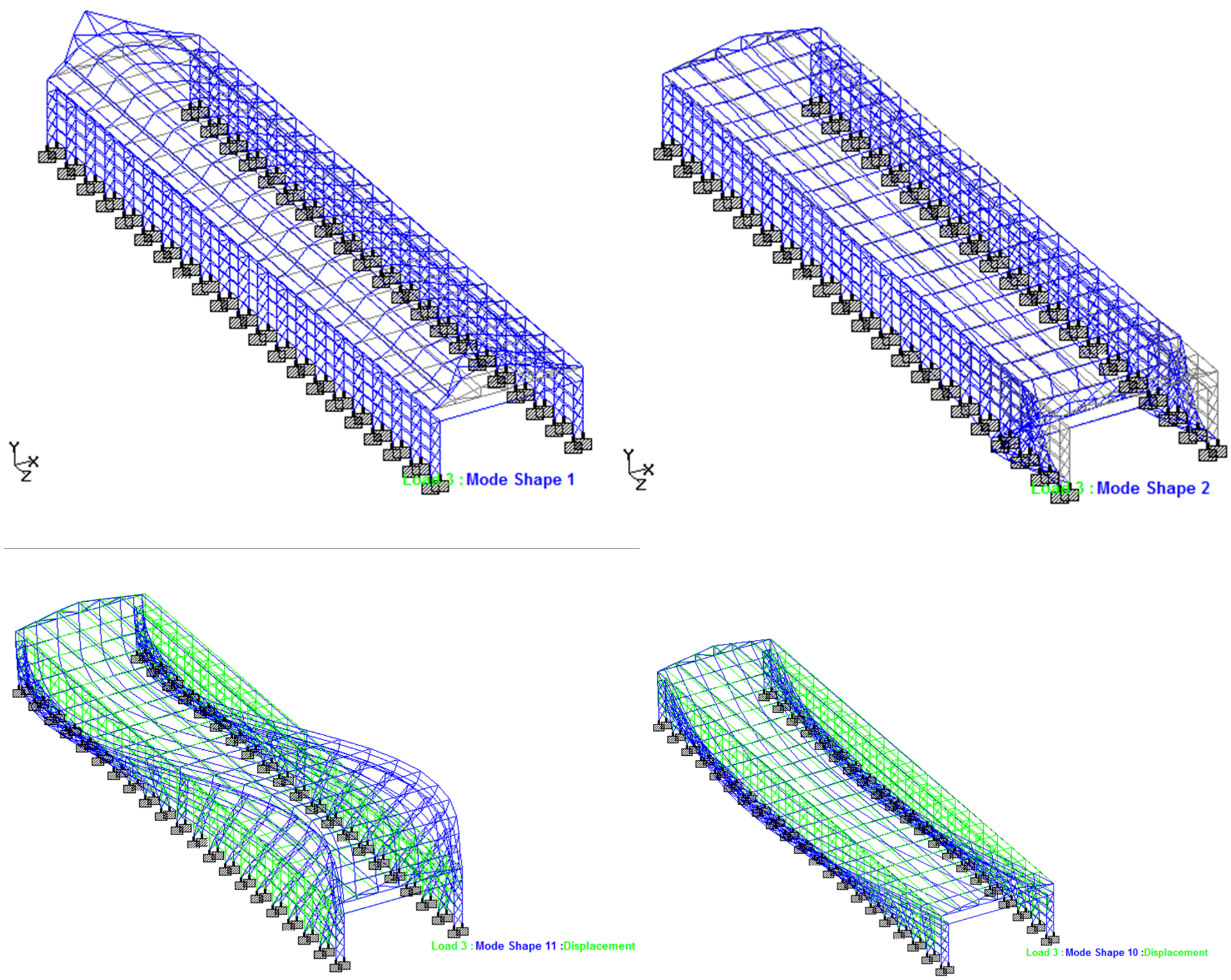


FIG 5.20: Mode Shapes for Time History Analysis



CHAPTER-6

CONCLUSION

Conclusion-

- ✓ Displacement is zero when the crane is at the point O i.e. at the supported end of the gantry girder. This may be because the lateral earthquake force is taken by the crane directly.
- ✓ The base shear is more when crane is located at point O, found through all methods of analysis.
- ✓ Maximum axial force in the Crane girder was observed when crane is located at the support of GG.
- ✓ The displacement along lateral and longitudinal direction increases as crane moves away from the critical point and reaches its peak value at the end of that span. The displacement values do not deviate much from the peak values when the crane is positioned beyond the adjacent span.
- ✓ After comparison between three methods of analysis it is observed that displacements obtained by static analysis are higher than dynamic analysis i.e. response spectrum and time history analysis in their first mode. It is also observed that base shear is maximum for Equivalent Static load method and minimum for Response Spectrum method. Intermediate values are obtained by Time history analysis. The maximum participation factor for Response spectrum method is observer to be 82.64% in first mode whereas in Time History analysis for Taiwan earthquake it is 76.24%.

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